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Enhanced photoluminescence in plasmonic resonant nanocavities

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Enhanced Photoluminescence in Plasmonic Resonant Nanocavities

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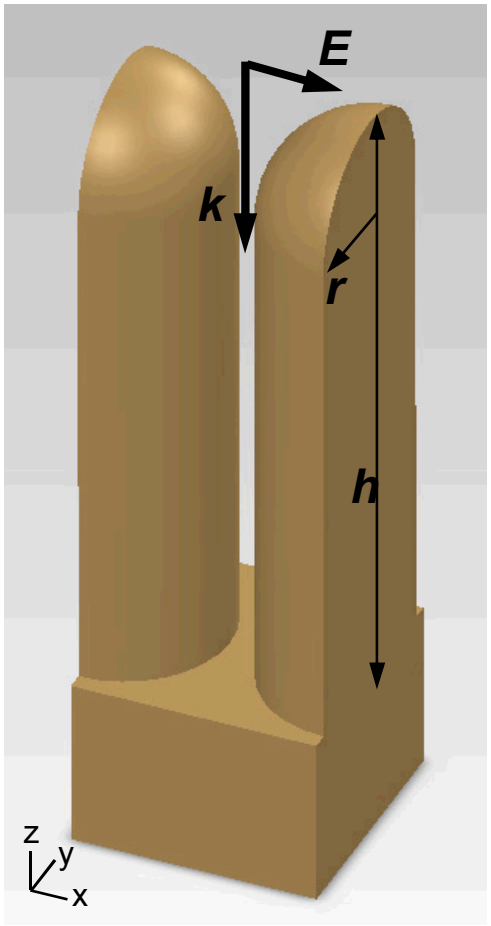
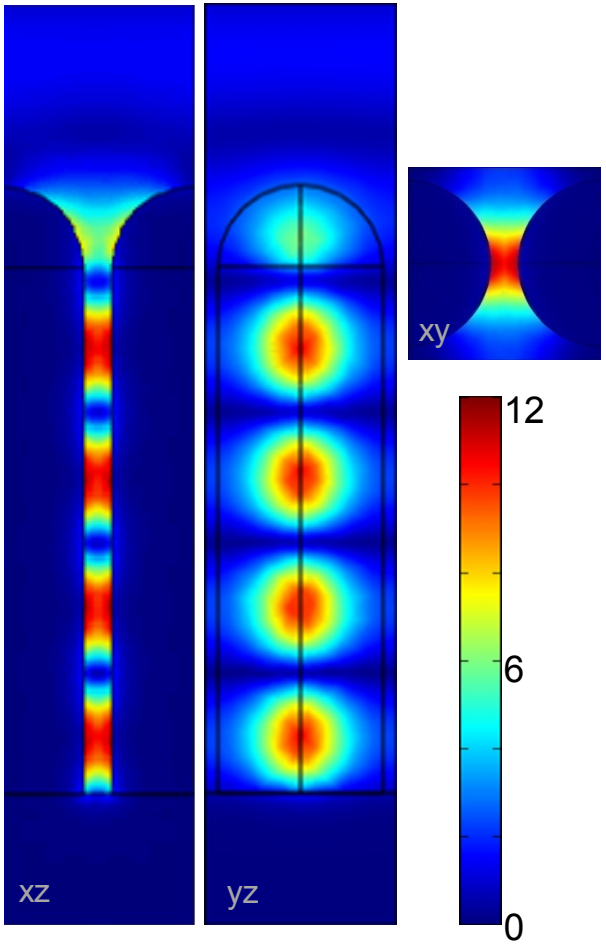
Lawrence Livermore National Laboratory

Plasmon resonant cavities

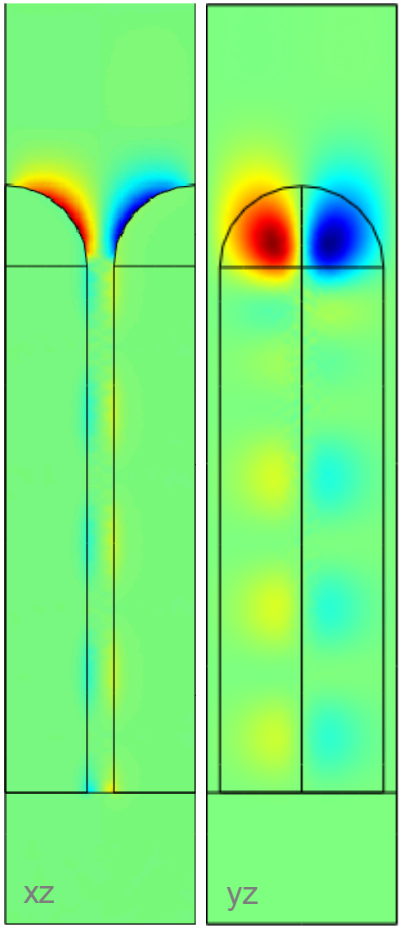
Geometry



Electric field profile

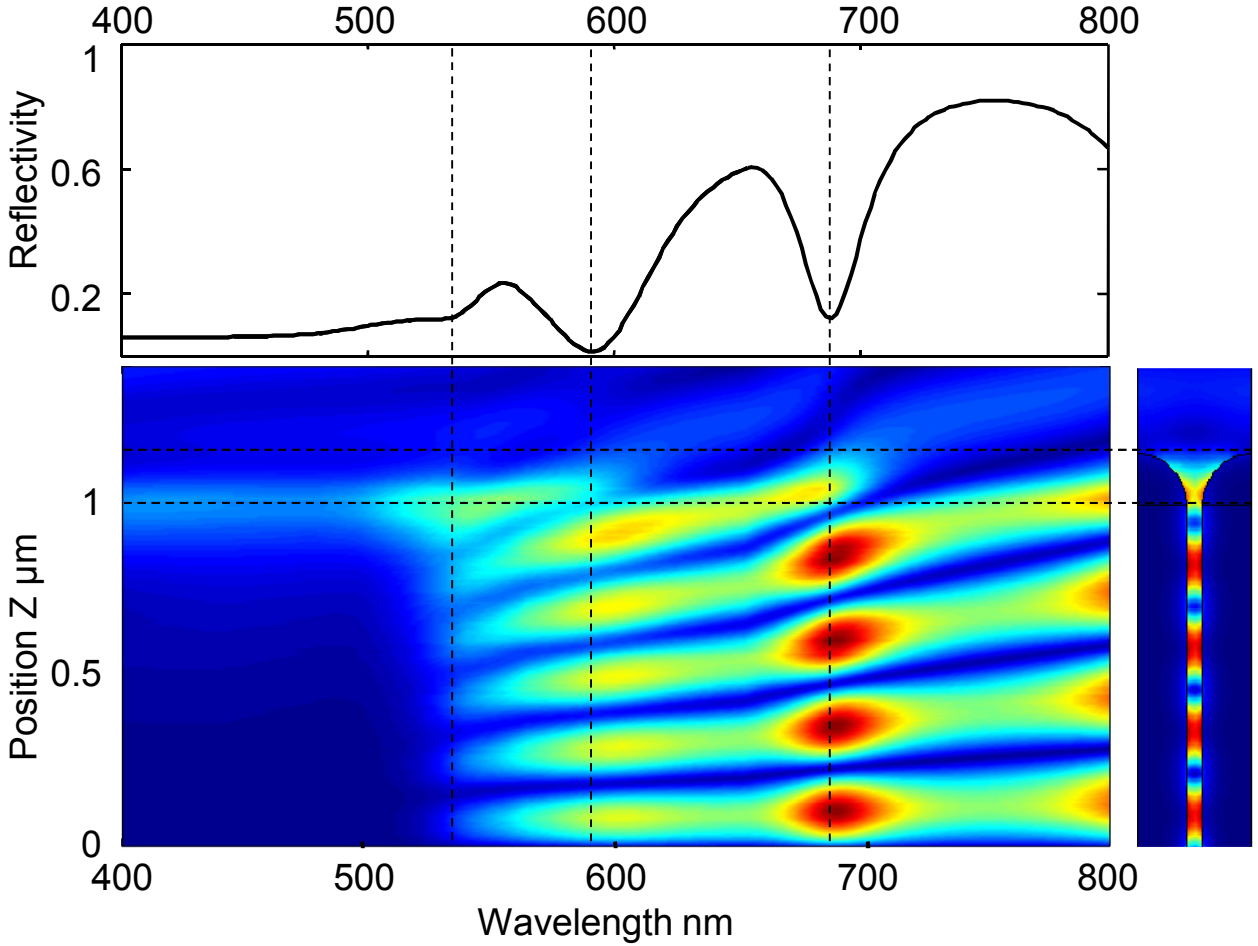


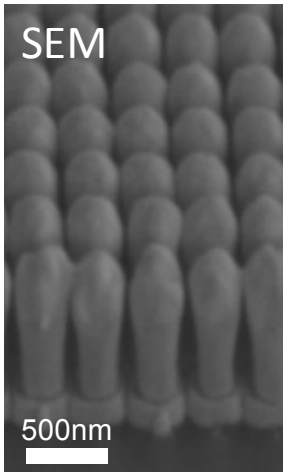
Power flow

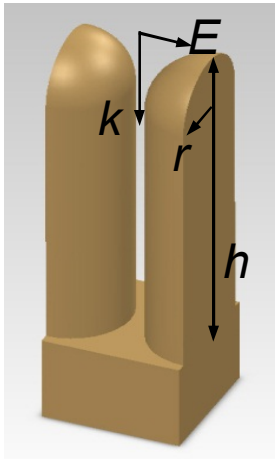


M. Bora et al. Nano Lett. **2010, 10, 2832–2837**

Plasmon coupling with incident radiation



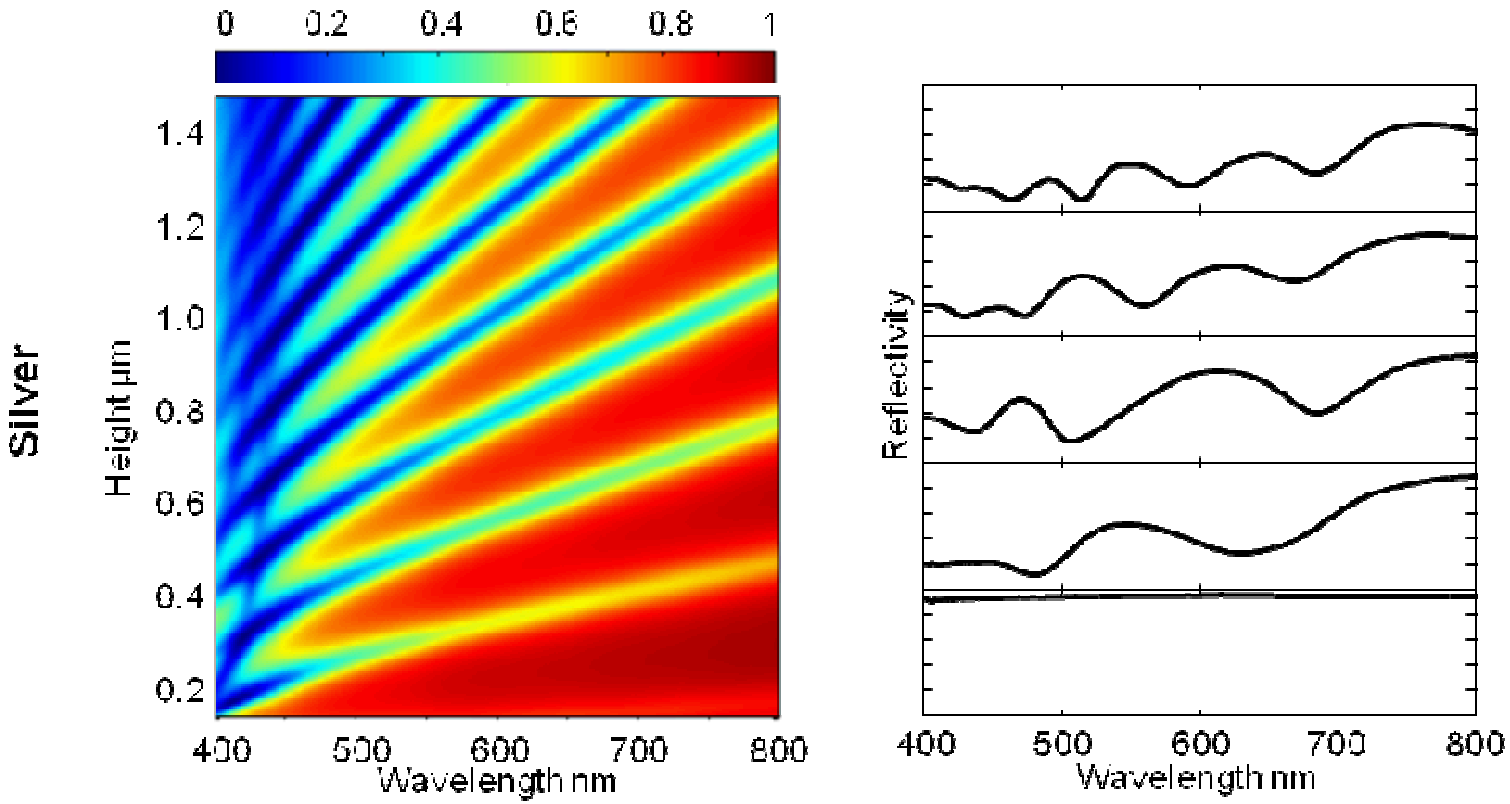




Tuning the plasmon resonance

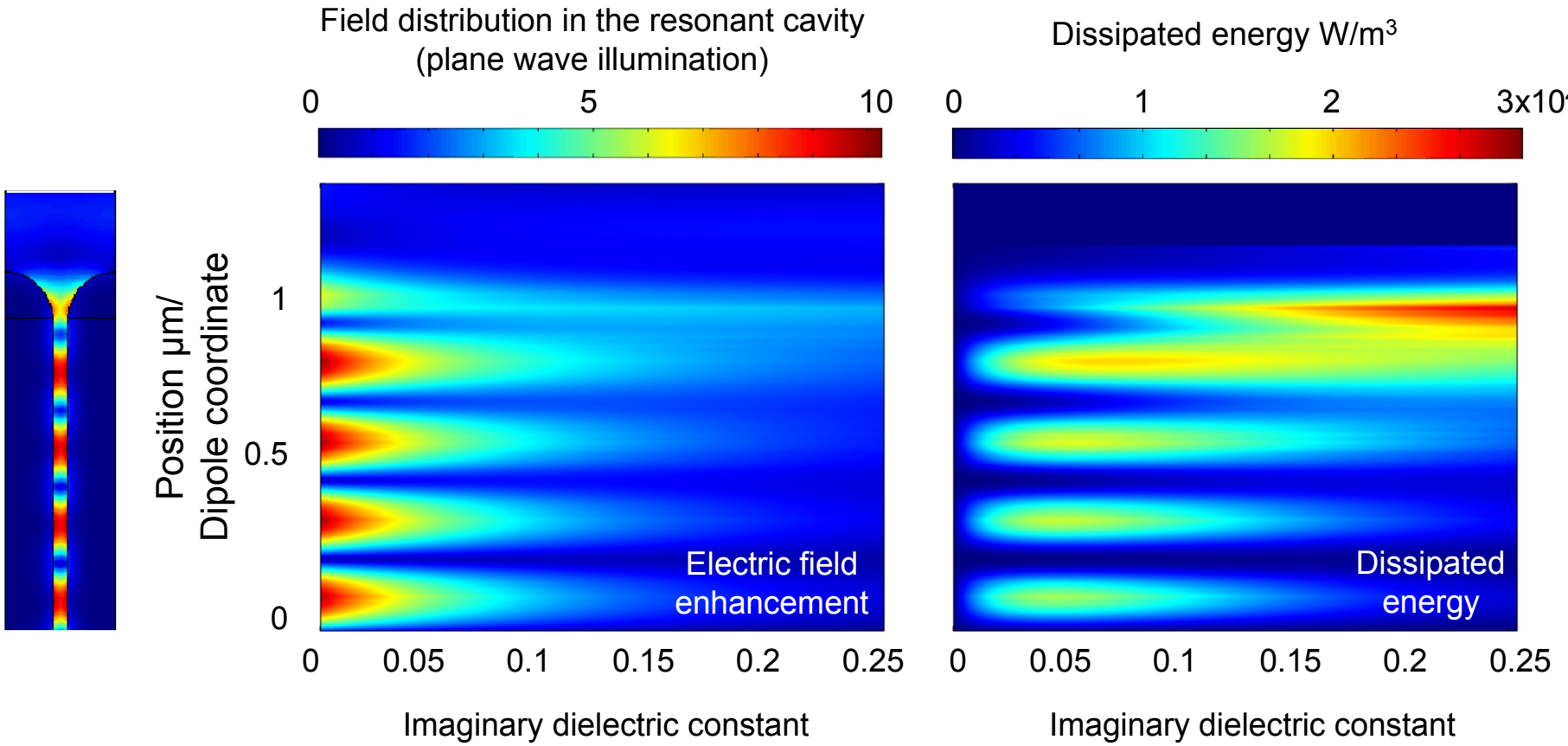
Simulated Reflectivity

Experimental Reflectivity



M. Bora et al. (submitted)

Enhanced dipole absorbance

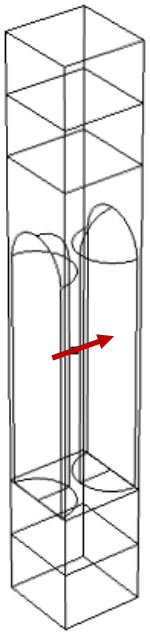


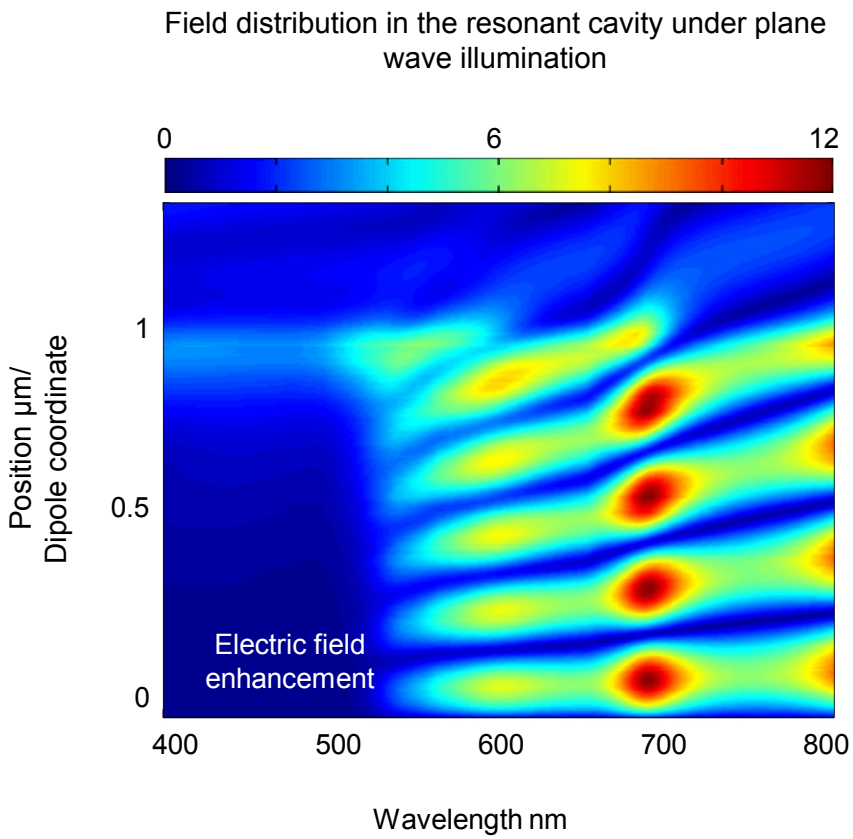
The field enhancement decreases with absorbance

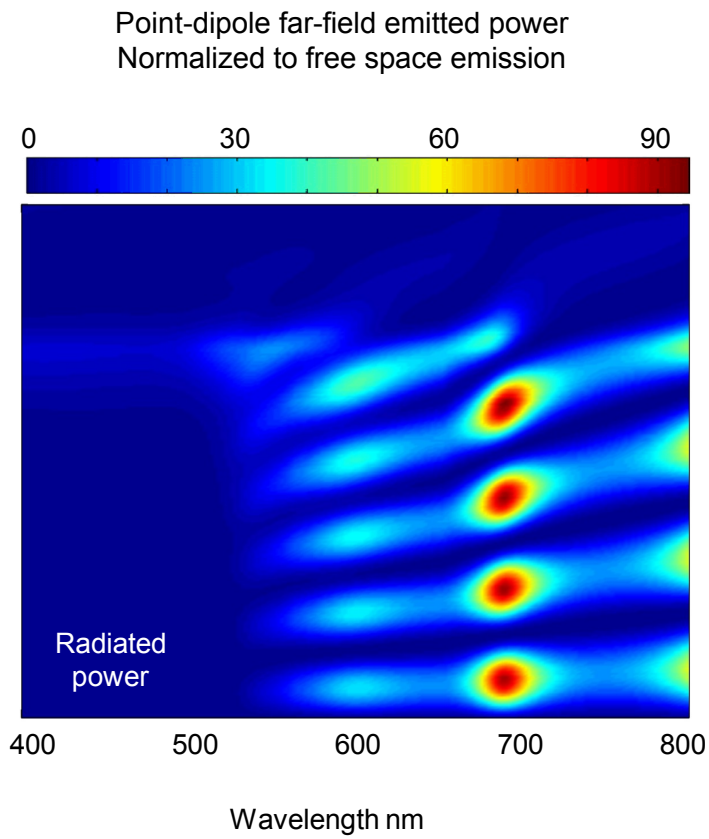
$$\alpha_{abs} = \frac{2\pi\varepsilon_{im}}{\lambda_0}$$

Dissipated energy in the cavity has a maximum with respect to ϵ_{im}

Enhanced dipole emission



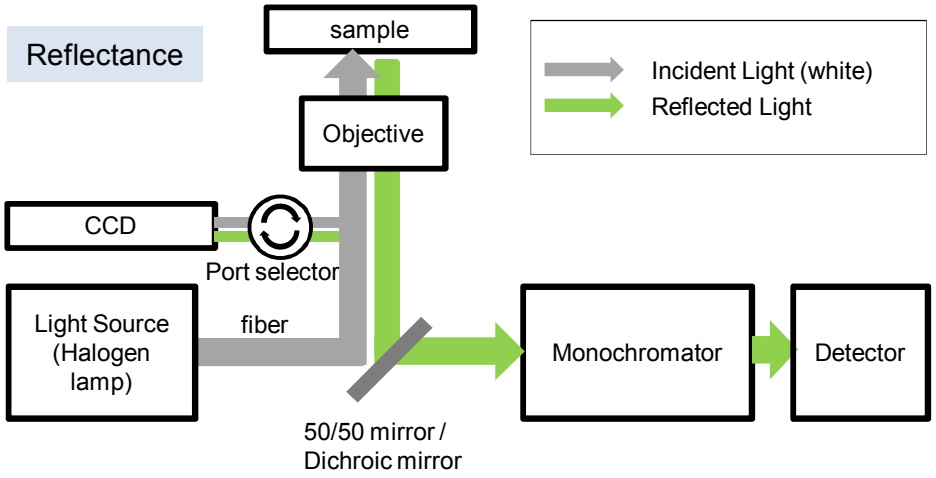


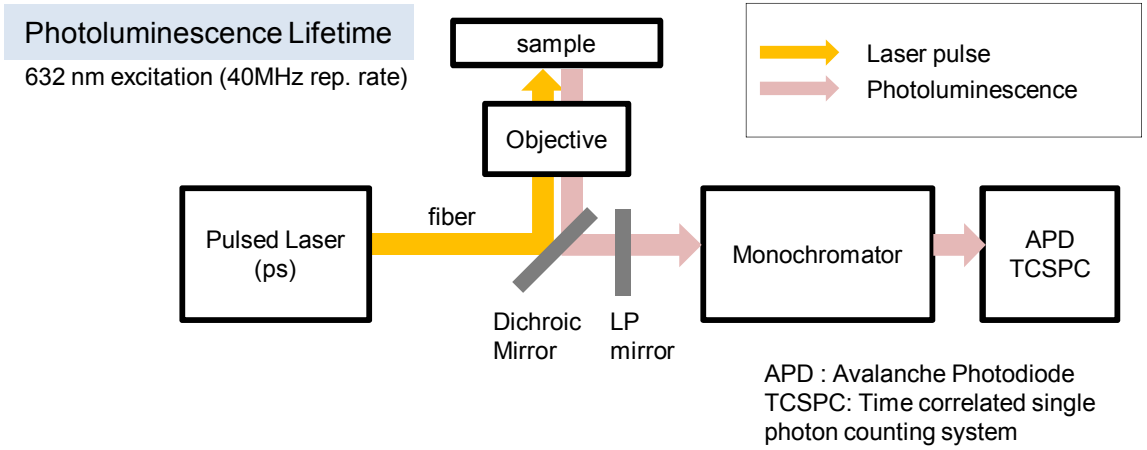


Point dipole emission profile from within the resonant cavity follows the electric field pattern of the resonant modes in both position and frequency

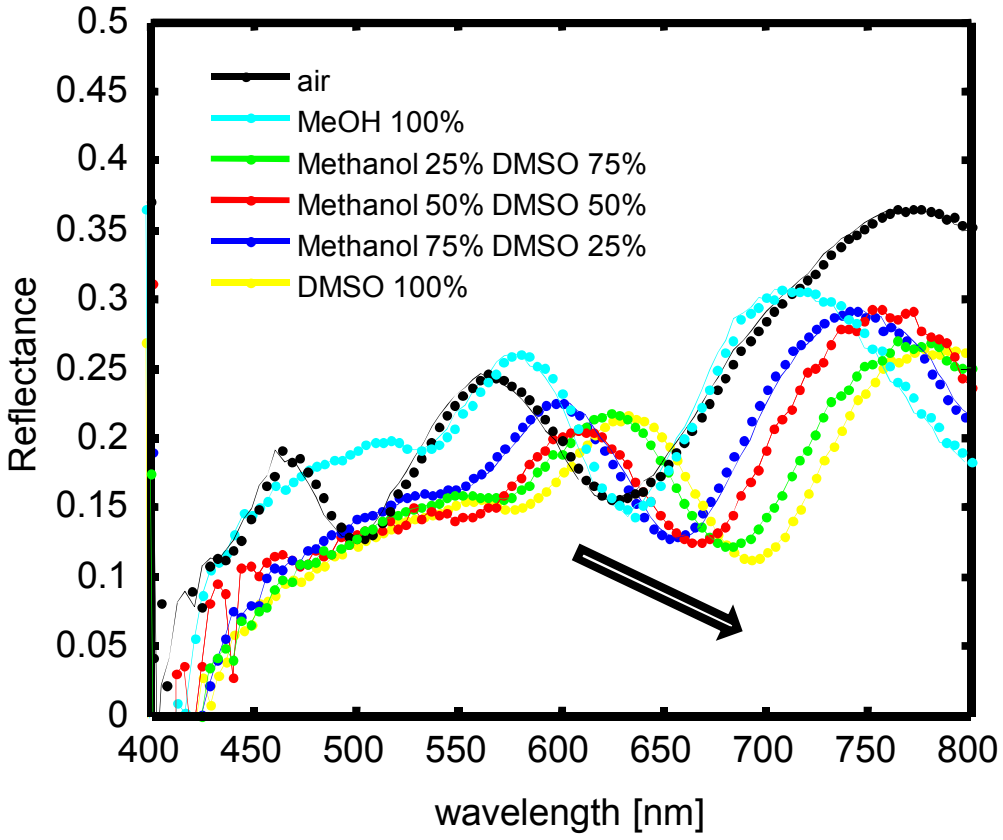
Emitted power ~ E^2

Experimental Setup



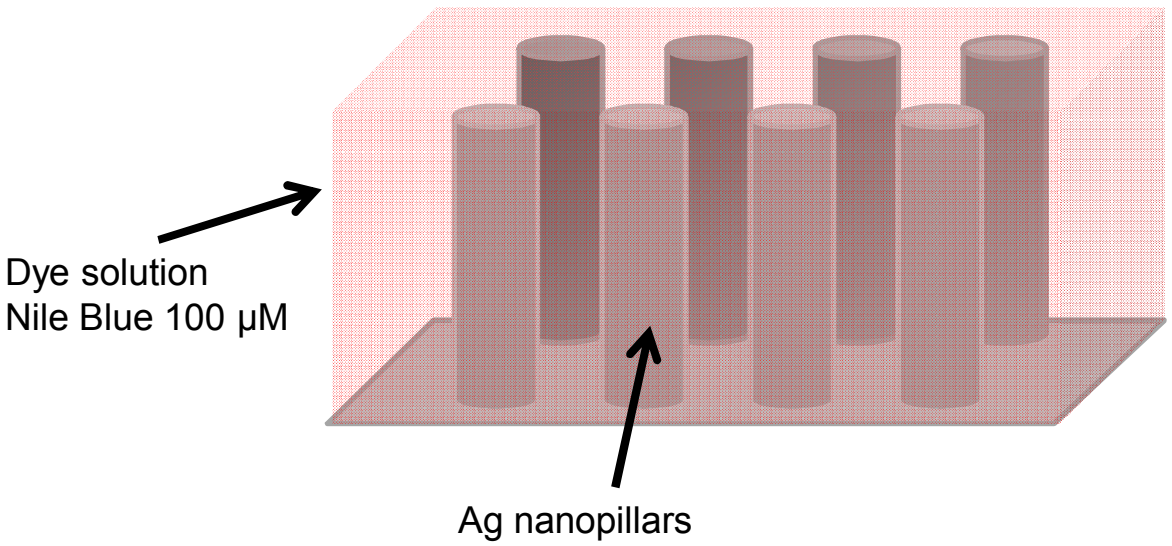


Tuning the plasmon resonance frequency with solvents

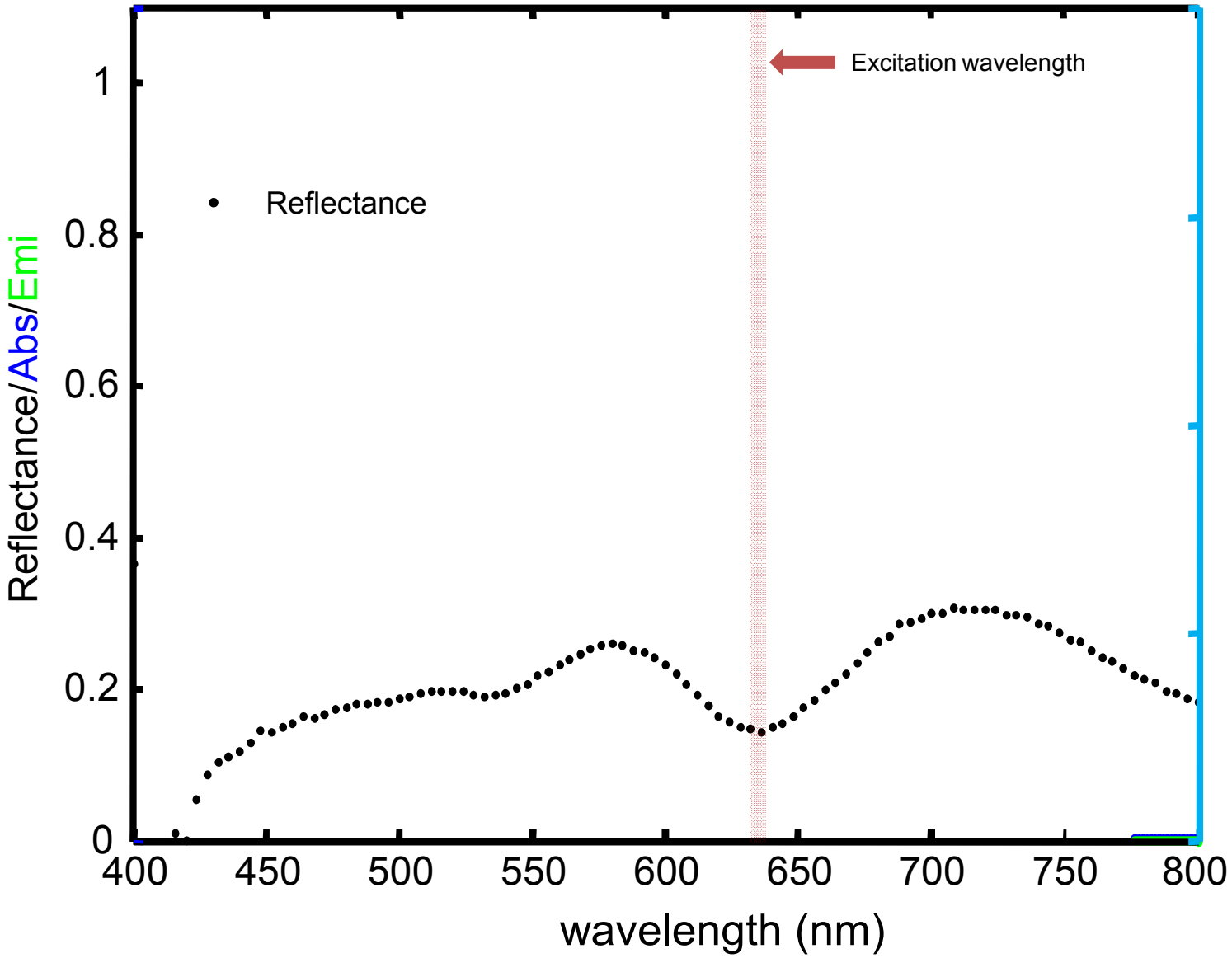


- Reflectance spectra of Ag nanocavities were measured while immersed in solvents with different refractive indices (methanol *n*= 1.328 and DMSO *n*=1.479).

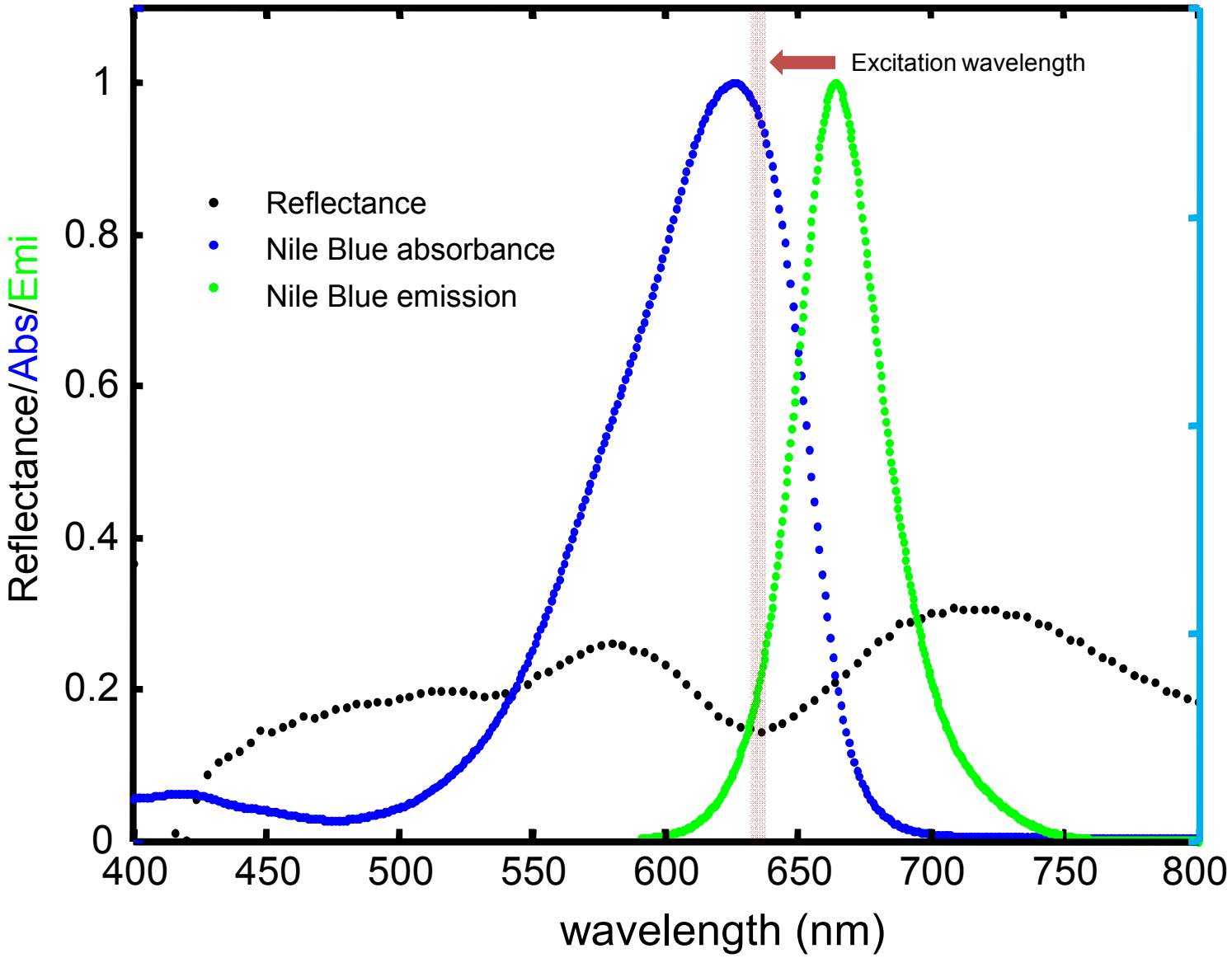
Sample Scheme



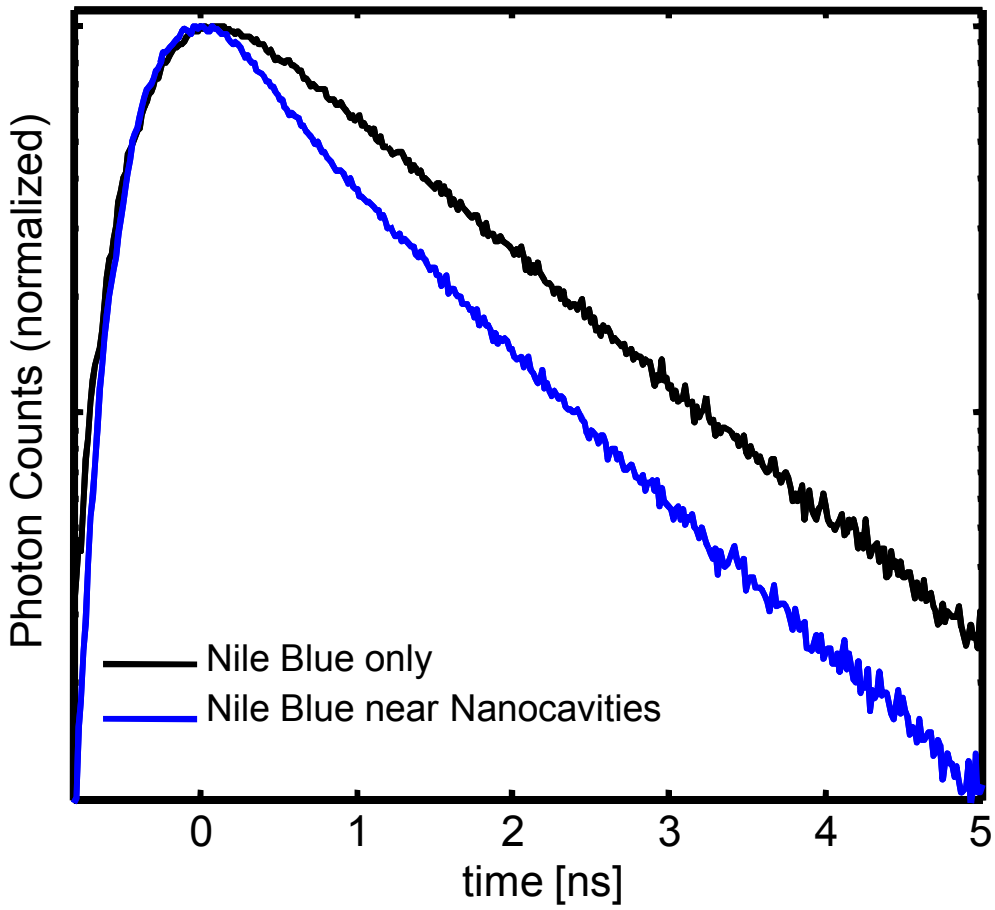
Correlated PL Lifetime / Reflectance



Correlated PL Lifetime / Reflectance

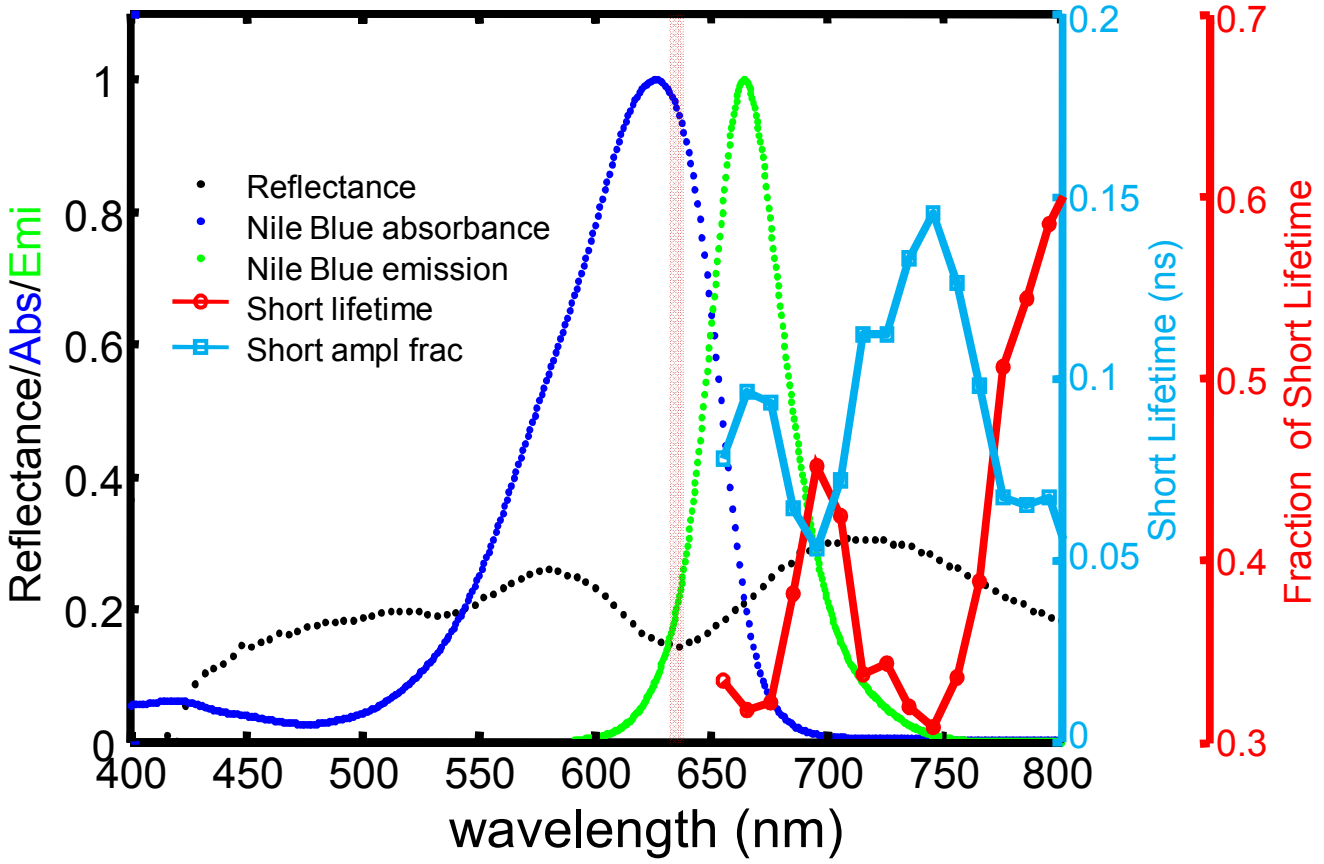


Correlated PL Lifetime / Reflectance



- ❑ Observed shortening of lifetime from the dyes within nanocavities
- ❑ Lifetime histograms were fitted to double exponential decay
- ❑ Lifetime was examined between 650 -800 nm (10 nm increments)

Correlated PL Lifetime / Reflectance



- ❑ Pristine Dye lifetime ~ 1.1 ns
- ❑ Short lifetime within nanocavities reduced down to ~ 0.06 ns (~ 20x reduction)
- ❑ Fraction of short lifetime (# of photons which had short lifetime) increased at the same time

Summary and Future Plans

- 3D arrays of nanowires show tunable plasmon resonances in the visible region (height & gap control)
- Plasmon resonance frequency of nanocavities can be tuned ~ 100 nm by changing the RI of solvents
- Observed reduced (~ 20X) photoluminescence lifetime of Nile Blue dyes on the plasmonic nanocavities
- Fraction of shorter lifetimes (compared to pristine dye photoluminescence lifetime) is maximized when the plasmon resonance frequency is off-resonance from the emission maxima
- Future work include parametric study and systematic control of plasmonic resonances with respect to dye excitation/emission frequency

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Thank you for your attention!